WCOSS Science Quarterly
09 July 2015

Rapid Refresh (RAP) v3.0
High-Resolution Rapid Refresh (HRRR) v2.0

NOAA/ESRL/GSD/EMB

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NOAA/NWS/NCEP

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Rapid Refresh and HRRR
NOAA hourly updated models

13km Rapid Refresh (RAP)

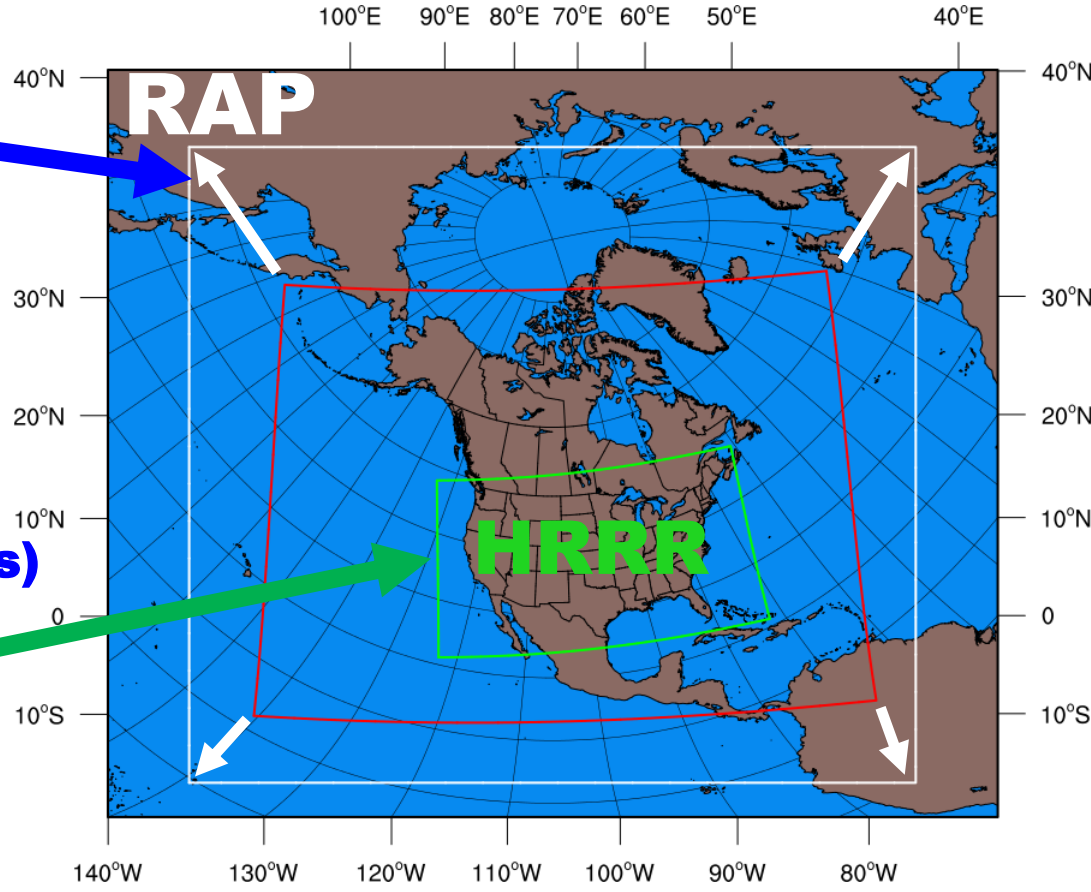
Version 2 -- NCEP
implemented 25 Feb 2014

Version 3 – GSD
Planned NCEP – Late 2015
Larger Domain (red → white)
Longer Forecasts (18 → 30? hrs)

3km High Resolution Rapid Refresh (HRRR)

Initial – NCEP
implemented 30 Sept 2014

Version 2 – GSD
Planned NCEP – Late 2015
Longer Forecasts (15 → 24? hrs)



Domain Expansion to match 12km NAM
Supports Improved SREF Initialization

RAP and HRRR R2O Schedule

Operational Implementations

May 2012 — RAPv1: Adoption of GSI, WRF-ARW and unified post
Enabled use of community-developed software

Feb 2014 — RAPv2: Hybrid DA
Significant Improvement in Upper-Air Forecasts

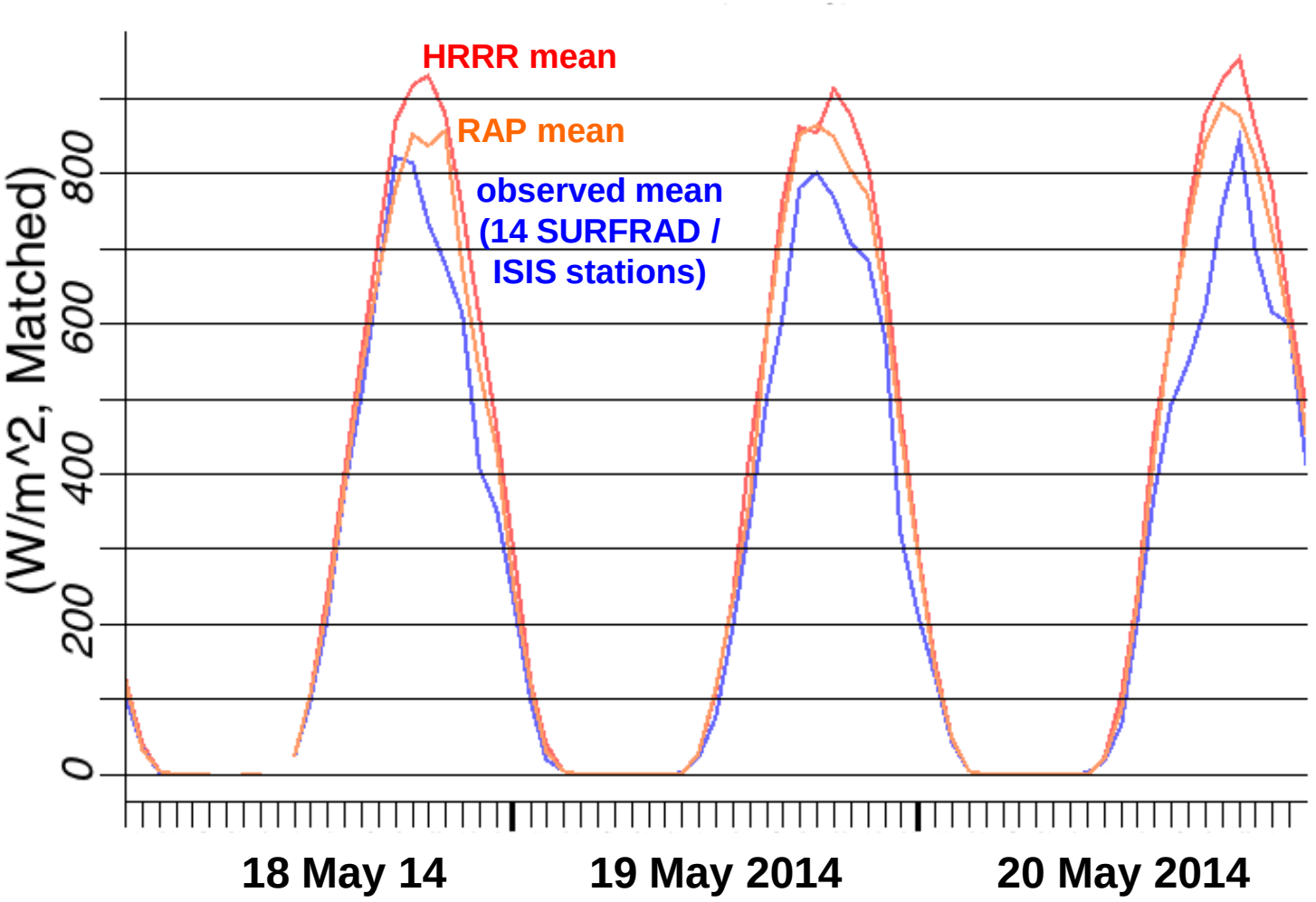
Sep 2014 — HRRRv1: 3-km Radar DA in WRF-ARW
Significant Improvement in Convective Forecasts
Another milestone thanks to the WRF-ARW community

Nov 2015 — RAPv3/HRRRv2:
Aerosol Thompson MP, MYNN PBL, RUC LSM, RRTMG Rad, GF Cu
Significant Improvement in Surface Forecasts

Cloud Deficiency in RAP and HRRR

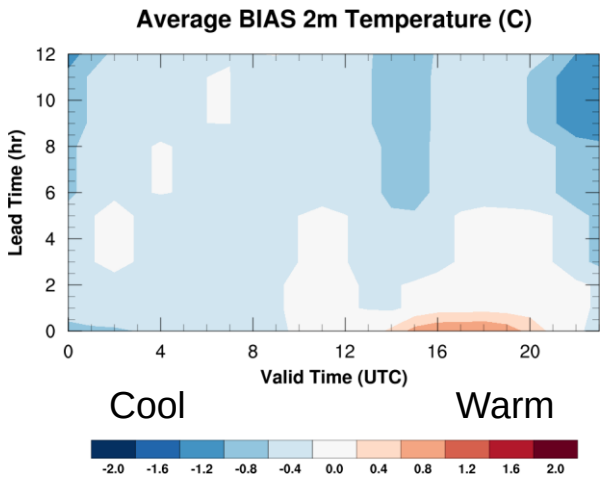
- A problem for convection/ceiling/terminal forecasts

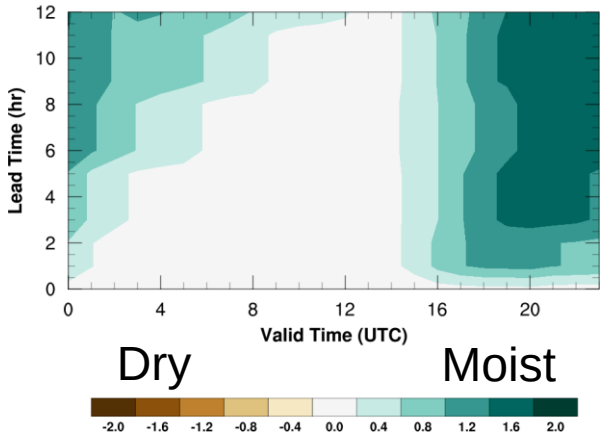
12-h forecasts of downward shortwave flux at surface



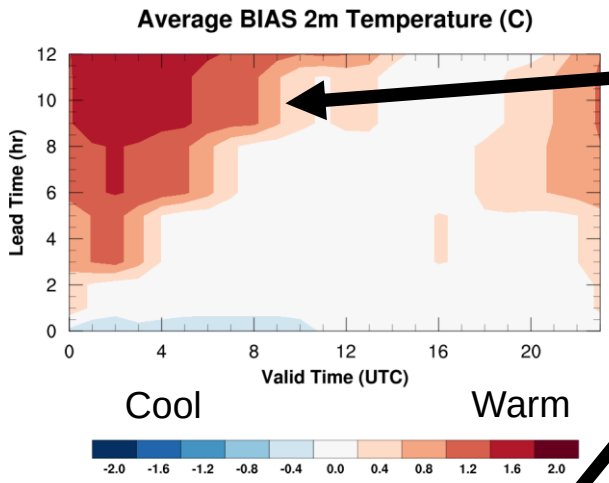
RAPv2/HRRRv1 Forecast Biases

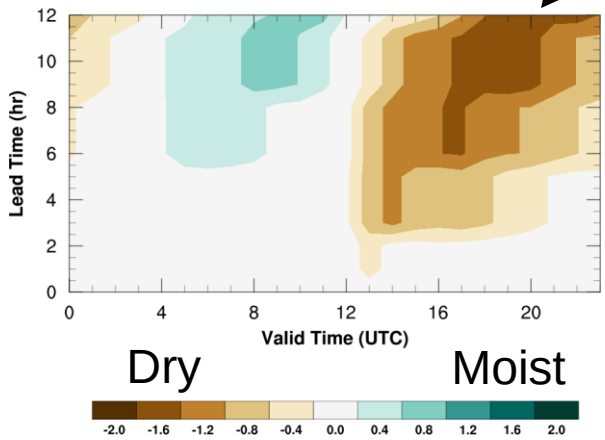
Winter (Jan-Mar)





Summer (Jul-Sep)





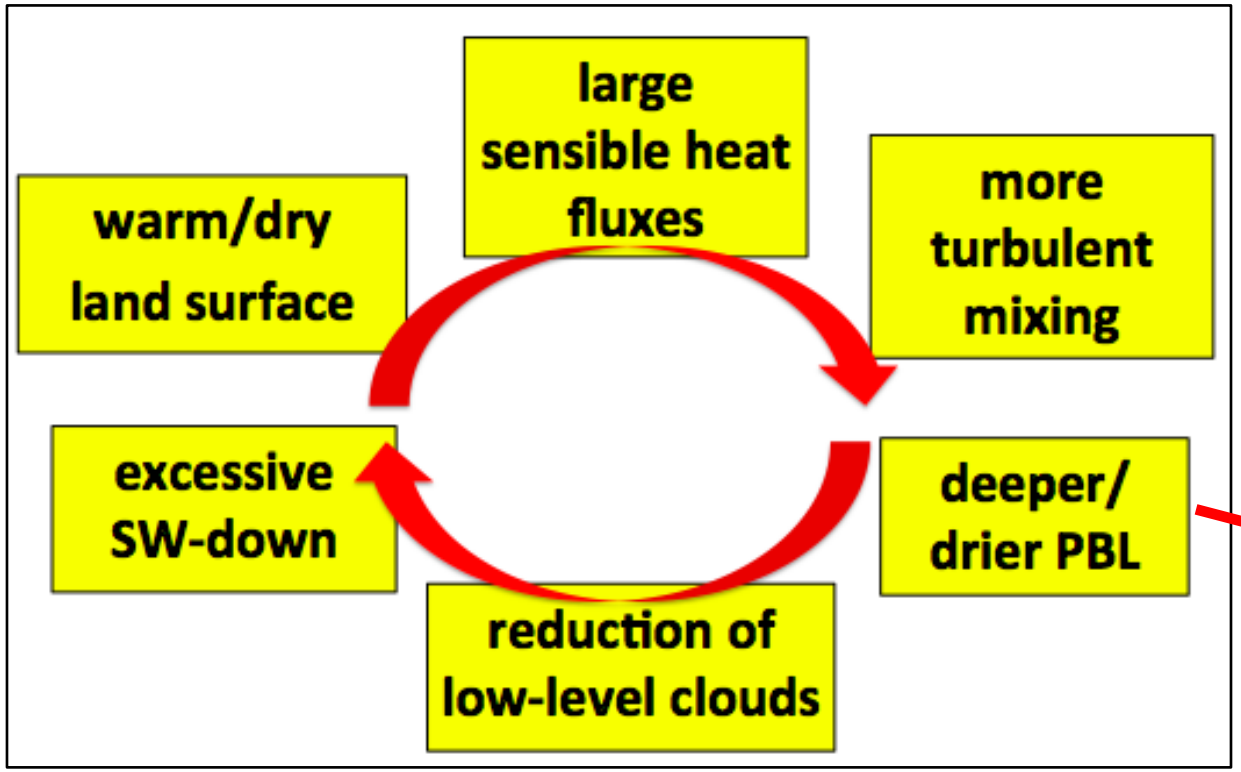
The RAP/HRRR has a daytime warm bias in the warm season.

The RAP/HRRR has a daytime dry bias in the warm season.

Experimental improvements to the model to remove bias have been made and will be implemented in RAPv3/HRRRv2.

RAPv2/HRRRv1 Model Bias Feedback

Conceptual Model of Positive Feedback Model Bias



Led to occasional spurious high-based convective initiation in more weakly-forced diurnally-driven events

HRRRv1 to v2 Reflectivity Forecast Skill

HRRRv1 (oper)

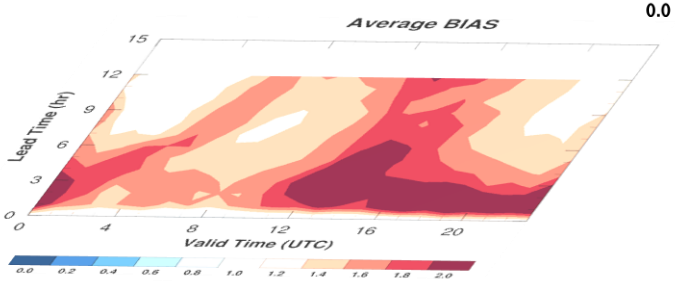
←Low Bias CREF High Bias→

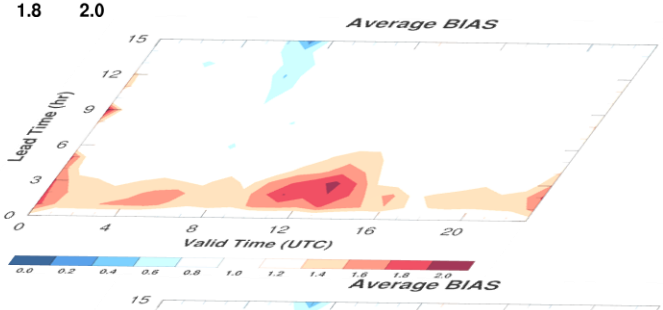
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0

HRRRv2 (exper)

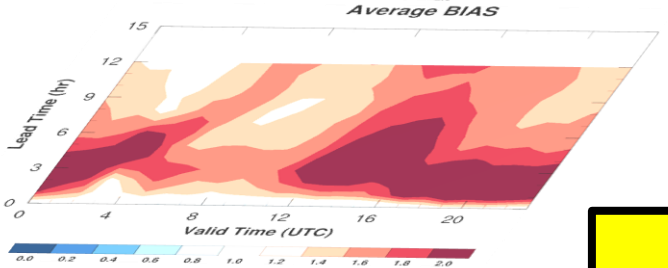
May-June 2015

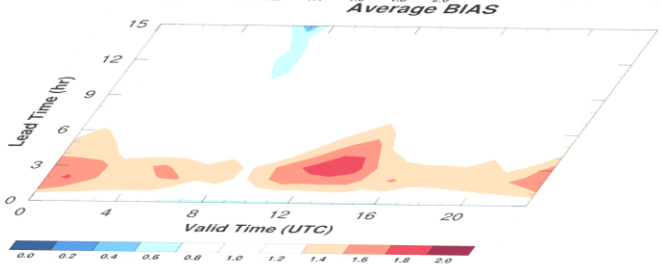
40 dBZ



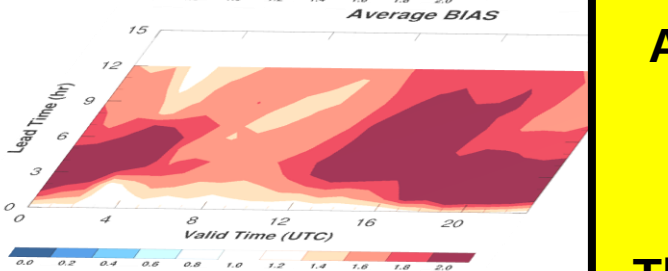


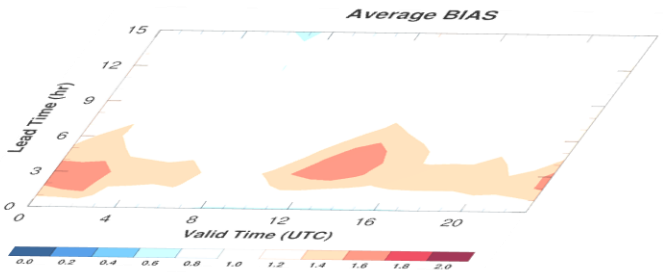
35 dBZ



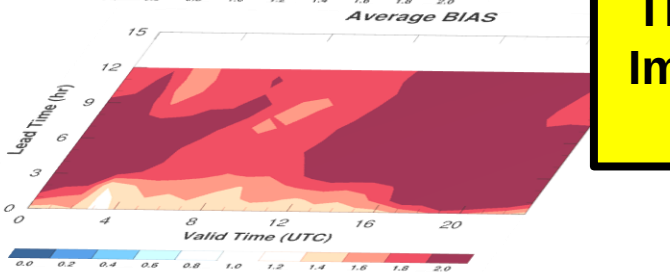


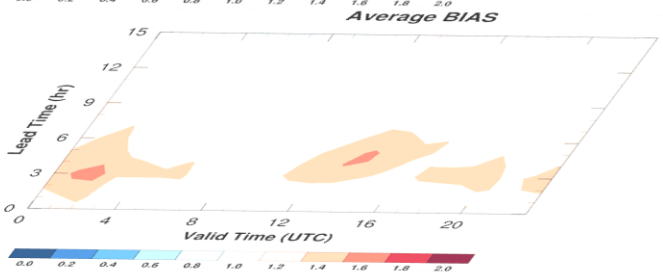
30 dBZ





25 dBZ

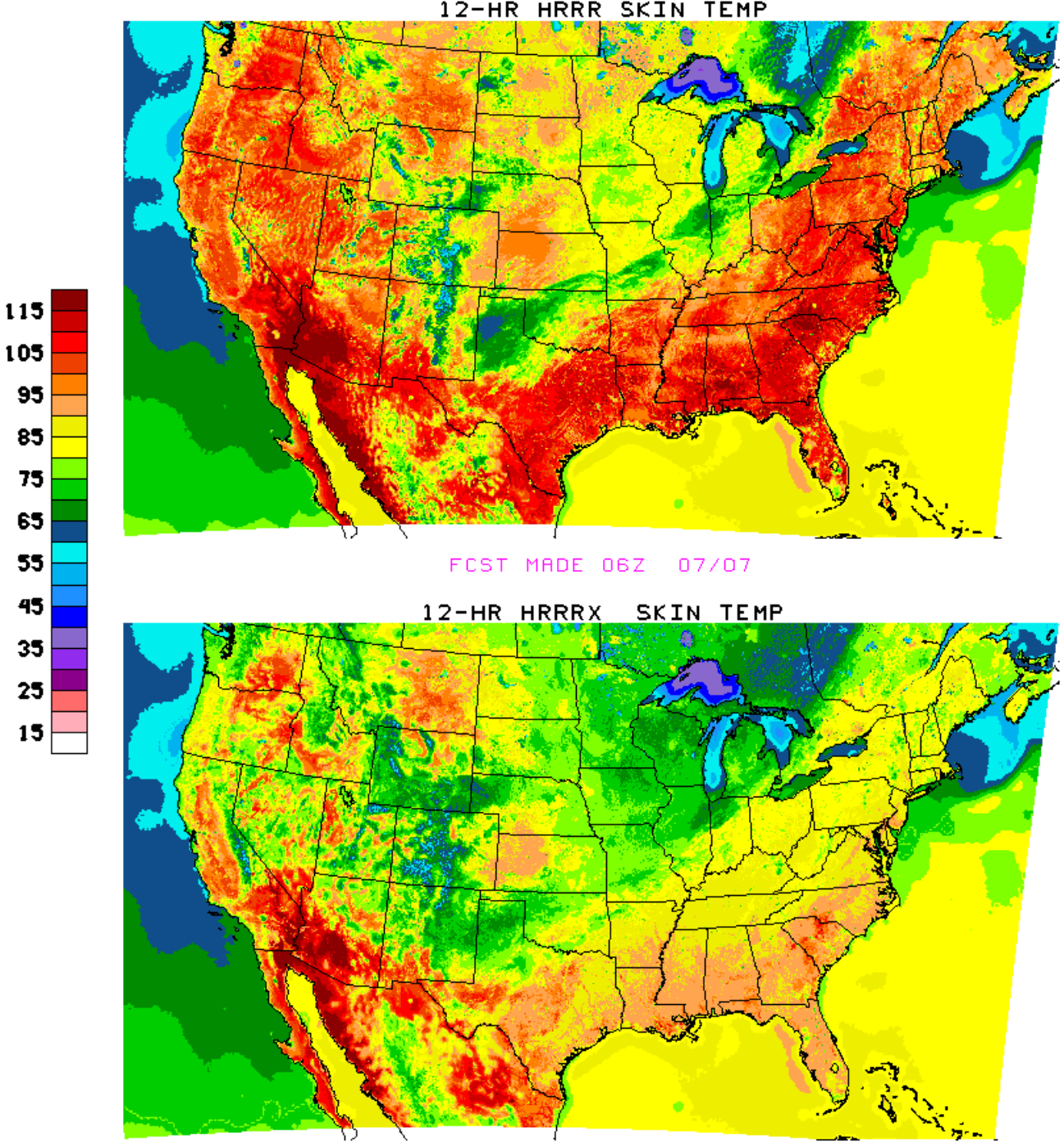




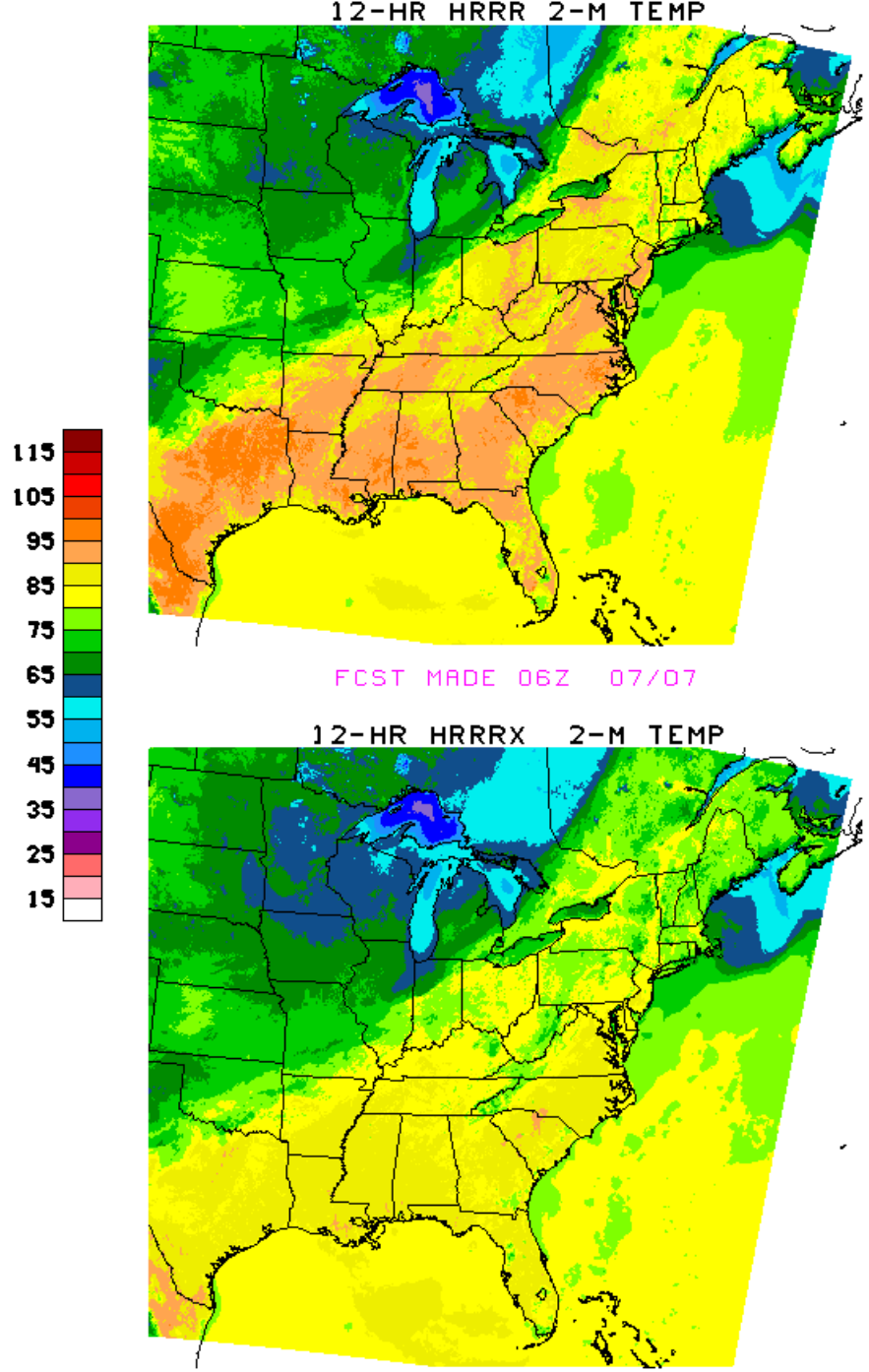
High Afternoon Bias Persists Lower Thresholds Improved in HRRRv2

RAPv3/HRRRv2 Warm/Dry Bias Mitigation

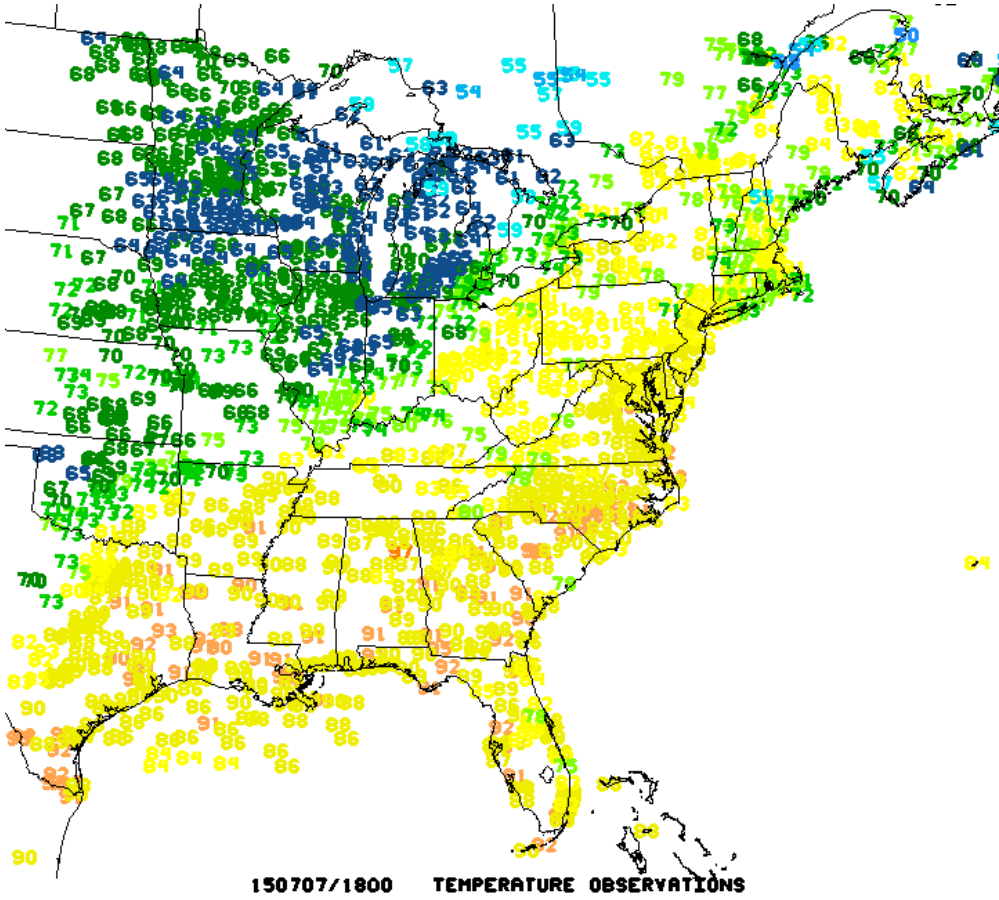
Component	Mitigating Items
GSI Data Assimilation	Canopy water cycling Temp pseudo-innovations thru model boundary layer More consistent use of surface temp/dewpoint data
GFO Convective Parameterization	Shallow cumulus radiation attenuation Improved retention of stratification atop mixed layer
Thompson Microphysics	Aerosol awareness for resolved cloud production Attenuation of shortwave radiation
MYNN Boundary Layer	Mixing length parameter changed Thermal roughness in surface layer changed Coupling boundary layer clouds to RRTMG radiation
RUC Land Surface Model	Reduced wilting point for more transpiration Keep soil moisture in croplands above wilting point



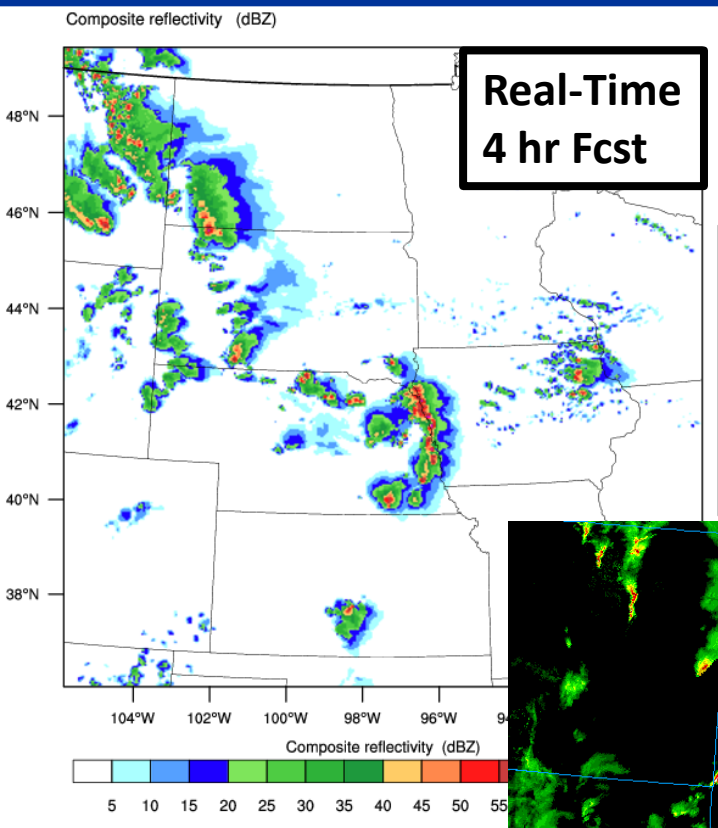
Huge reductions in skin temps



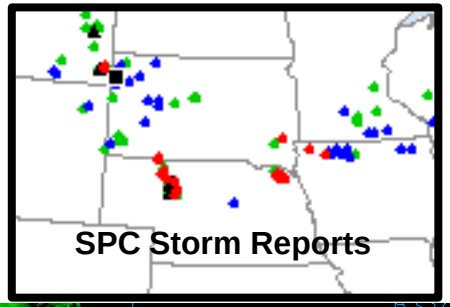
With significant positive impact on 2-m temps

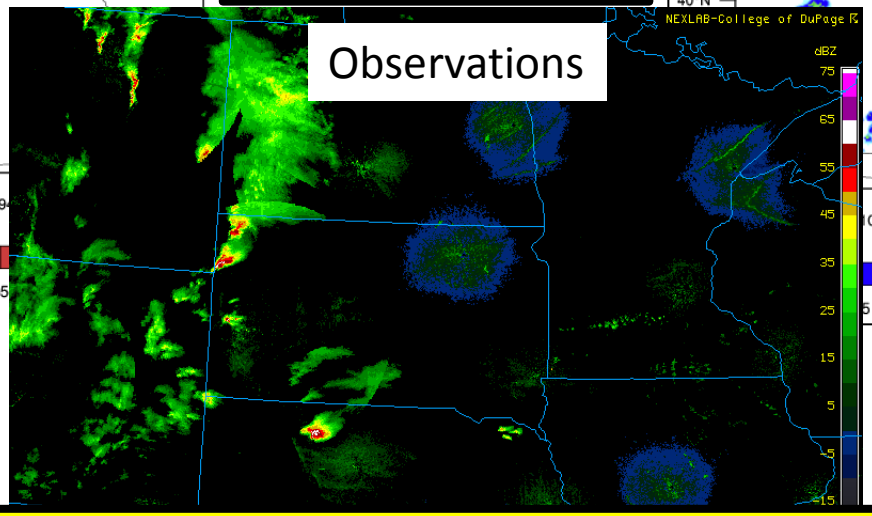


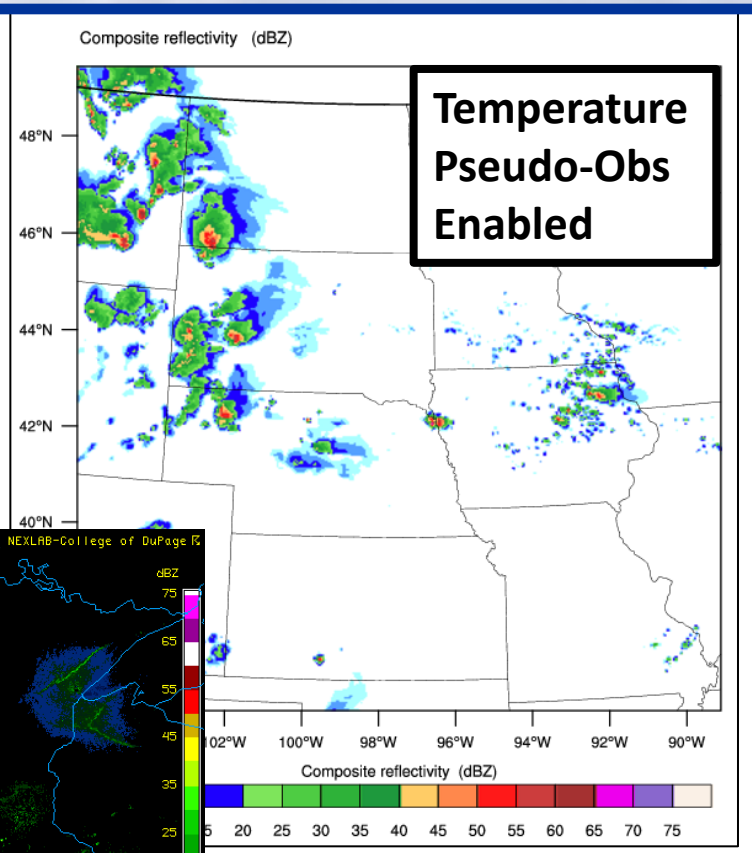
HRRR Convective Case Study



00 UTC
18 June 2014
Coleridge, NE

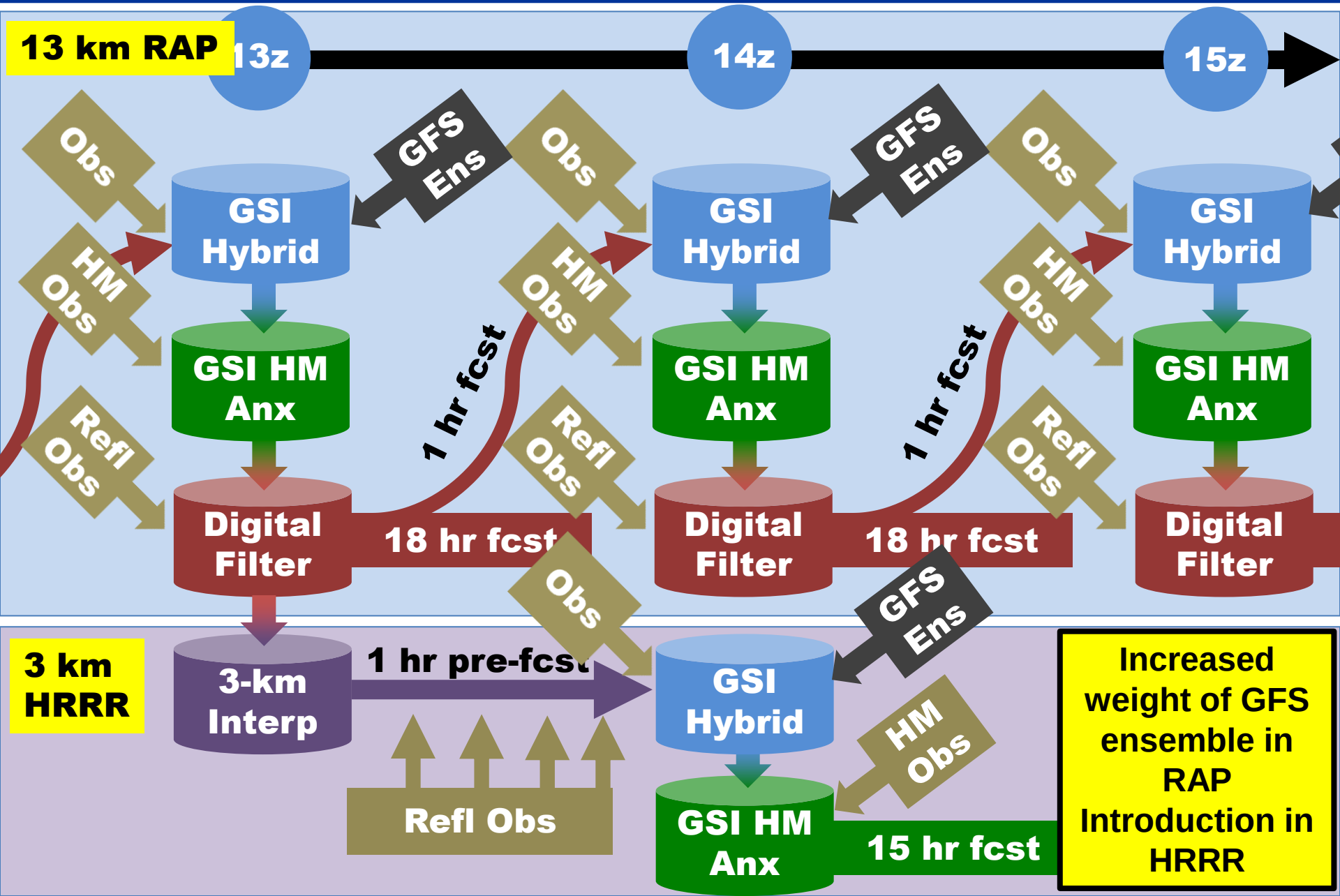






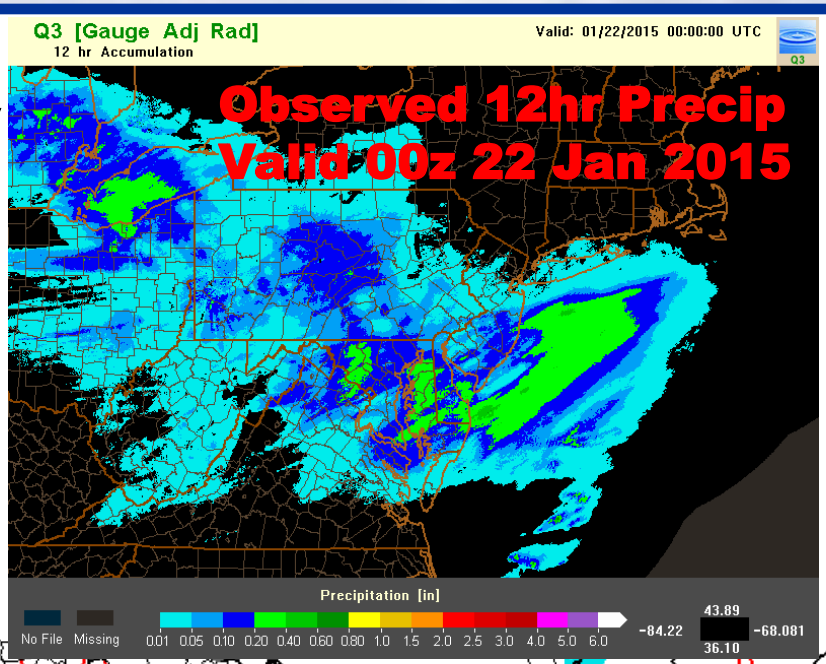
Control run develops too much high-based convection that grows upscale
Data assimilation change improves timing and evolution of convection

HRRRv2 Initialization from RAPv3



HRRR Winter Case Study

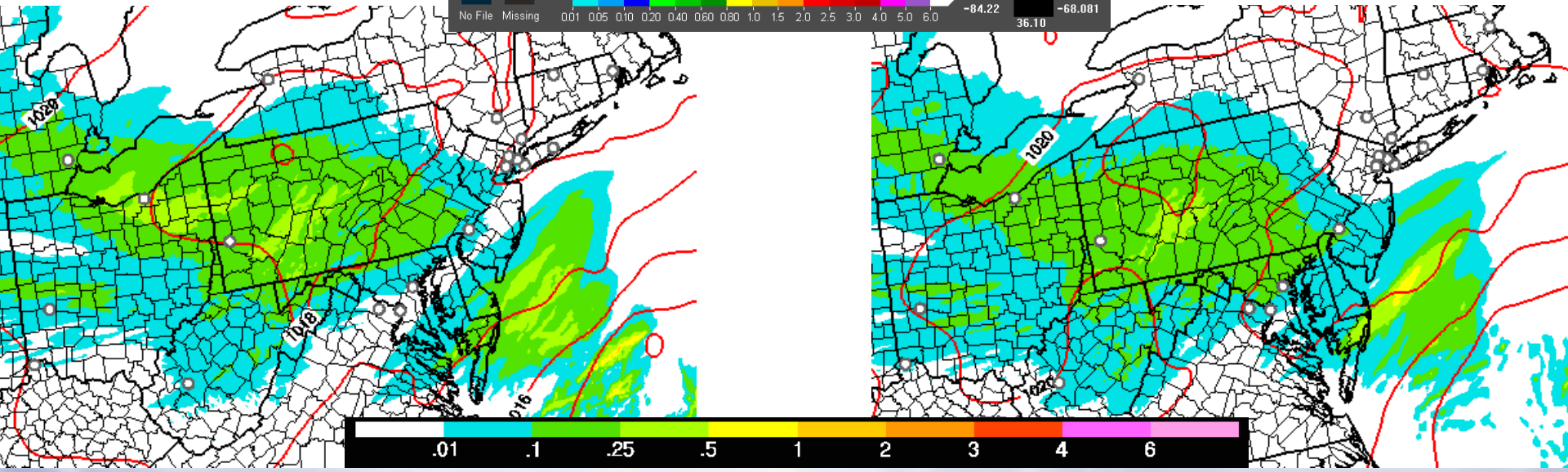
"Clipper" System Produced 1-2" snow D.C. Metro 21 Jan 2015



More precipitation produced in D.C. and northern suburbs

Oper HRRR 12 hr fcst Valid 00z 22 Jan 2015

Exper HRRR 12 hr fcst Valid 00z 22 Jan 2015



Operational RAPv2 and HRRRv1

Model	Run at:	Domain	Grid Points	Grid Spacing	Vertical Levels	Pressure Top	Boundary Conditions	Initialized
RAP	GSD, NCO	North America	758 x 567	13 km	50	10 mb	GFS	Hourly (cycled)
HRRR	GSD, NCO	CONUS	1799 x 1059	3 km	50	20 mb	RAP	Hourly (pre-forecast hour cycle)

Model	Version	Assimilation	Radar DA	Radiation LW/SW	Microphysics	Cumulus Param	PBL	LSM
RAP	WRF-ARW v3.4.1+	GSI Hybrid 3D-VAR/Ensemble	13-km DFI	RRTM/ Goddard	Thompson v3.4.1	G3 + Shallow	MYNN	RUC
HRRR	WRF-ARW v3.4.1+	GSI 3D-VAR	3-km 15-min LH	RRTM/ Goddard	Thompson v3.4.1	None	MYNN	RUC

Model	Horiz/Vert Advection	Scalar Advection	Upper-Level Damping	6th Order Diffusion	SW Radiation Update	Land Use	MP Tend Limit	Time-Step
RAP	$5^{th}/5^{th}$	Positive-Definite	w-Rayleigh 0.2	Yes 0.12	10 min	MODIS Fractional	0.01 K/s	60 s
HRRR	$5^{th}/5^{th}$	Positive-Definite	w-Rayleigh 0.2	No	5 min	MODIS Fractional	0.07 K/s	20-23 s

RAPv3 / HRRRv2 – 2015 Changes

Model	Run at:	Domain	Grid Points	Grid Spacing	Vertical Levels	Pressure Top	Boundary Conditions	Initialized
RAP	GSD, NCEP	North America	953 x 834	13 km	50	10 mb	GFS	Hourly (cycled)
HRRR	GSD, NCEP	CONUS	1799 x 1059	3 km	50	20 mb	RAP	Hourly (pre-forecast hour cycle, LSM full)

Model	Version	Assimilation	Radar DA	Radiation LW/SW	Microphysics	Cumulus Param	PBL	LSM
RAP	WRF-ARW v3.6+	GSI Hybrid 3D-VAR/Ensemble to 0.75	13-km DFI + low reflect	RRTMG/RRTMG	Thompson – aerosol v3.6.1	GFO v3.6+	MYNN v3.6+	RUC v3.6+
HRRR	WRF-ARW v3.6+	3km: GSI Hybrid 3D-VAR/Ensemble to 0.75	3-km 15-min LH +low reflect	RRTMG/ RRTMG	Thompson – aerosol v3.6.1	MYNN PBL Clouds	MYNN v3.6+	RUC v3.6+

Model	Horiz/Vert Advection	Scalar Advection	Upper-Level Damping	6th Order Diffusion	SW Radiation Update	Land Use	MP Tend Limit	Time-Step
RAP	$5^{th}/5^{th}$	Positive-Definite	w-Rayleigh 0.2	Yes 0.12	20 min	MODIS Fractional	0.01 K/s	60 s
HRRR	$5^{th}/5^{th}$	Positive-Definite	w-Rayleigh 0.2	Yes 0.25 (flat terr)	15 min with SW-dt (Ruiz-Arias)	MODIS Fractional	0.07 K/s	20 s

RAPv3/HRRRv2-2015 Changes

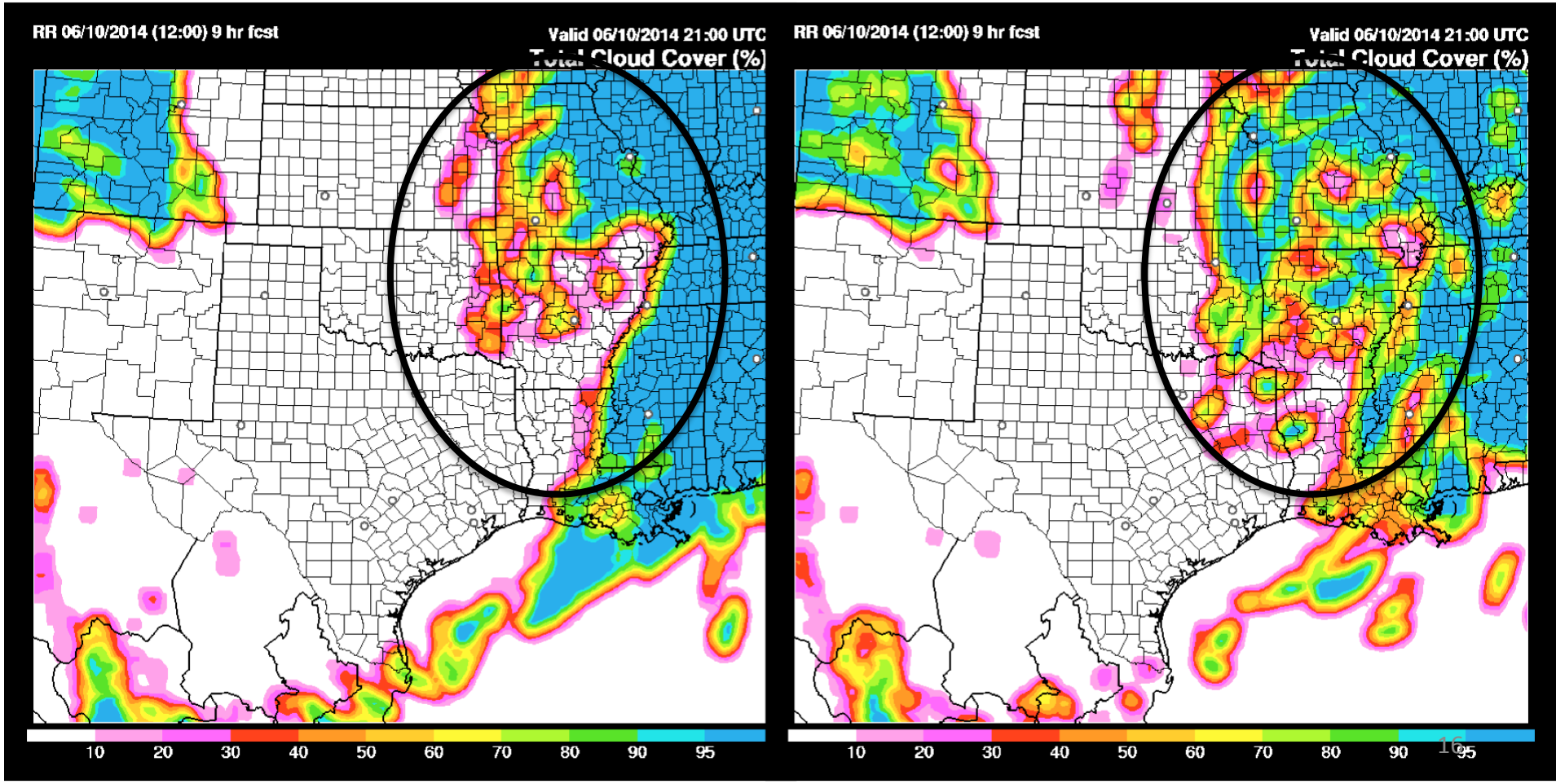
Use of forecast aerosol fields to have prognostic cloud-condensation nuclei (CCN).

Example: RAP cold-start tests without/with aerosol-aware cloud microphysics.

More small-scale cloud with more CCN over land.

WRFv3.5.1 aerosol unaware

WRFv3.6 Aerosol-aware

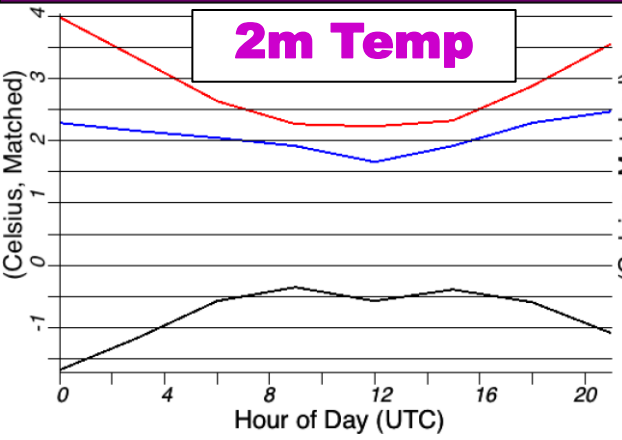


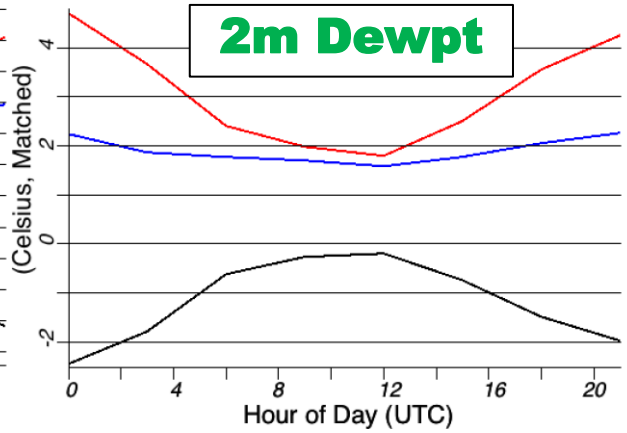
RAPv3 Retrospective Verification

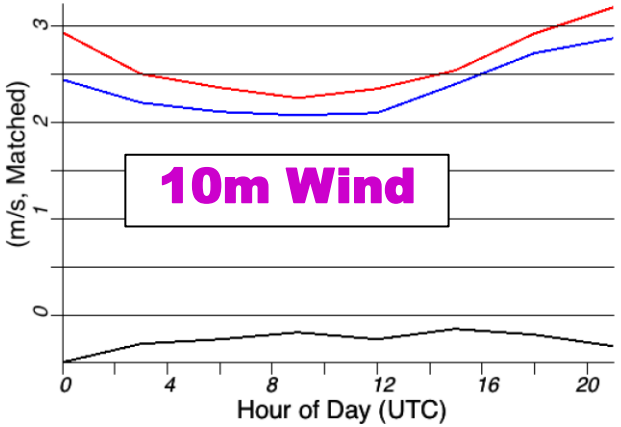
Eastern US 15 Jul – 15 Aug 2014

Exper RAPv3 **Oper RAPv2** **RAPv3 - RAPv2 Difference**

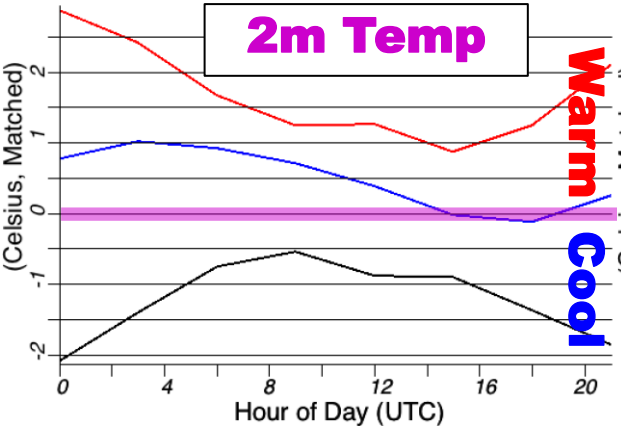
RAP Surface 12-hr Forecast RMSE

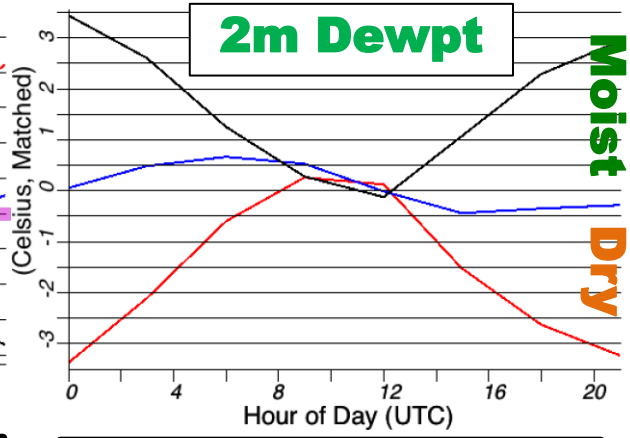


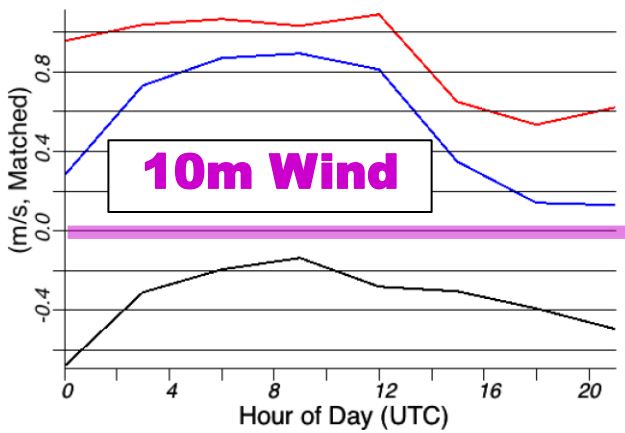




RAP Surface 12-hr Forecast Bias







Reduced warm bias

Reduced dry bias

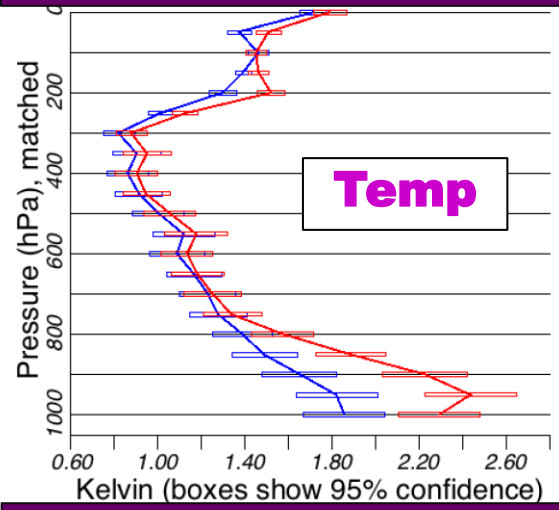
Reduced fast bias

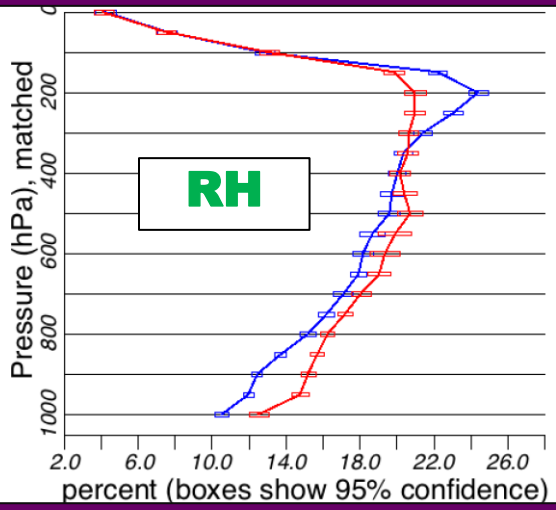
RAPv3 Retrospective Verification

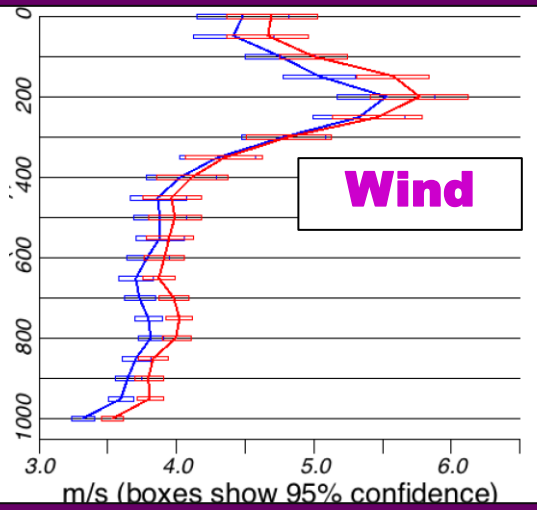
US 15 Jul – 15 Aug 2014

Exper RAPv3 **Oper RAPv2** **RAPv3 - RAPv2 Difference**

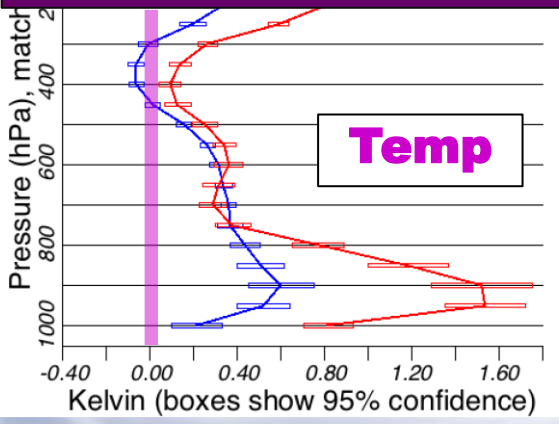
RAP Upper-Air 12-hr Forecast RMSE

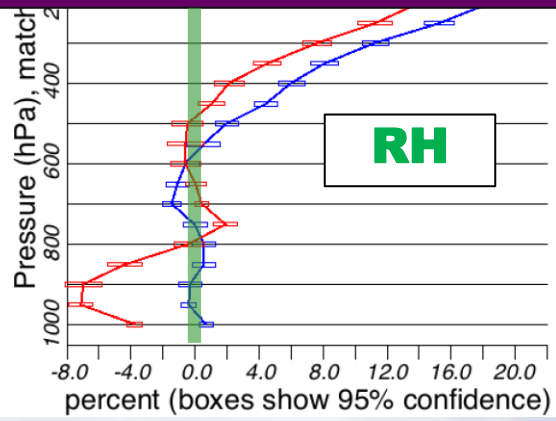


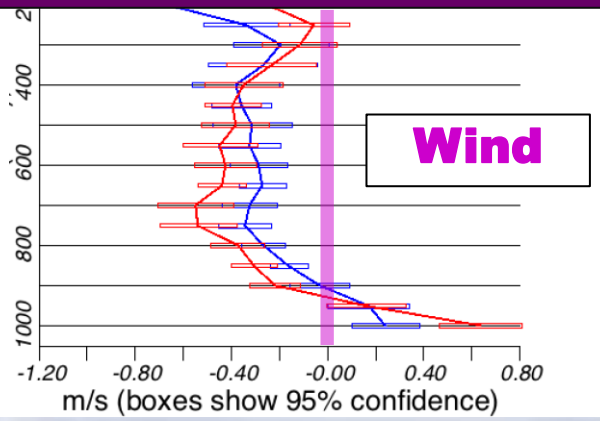




RAP Upper-Air 12-hr Forecast BIAS (00 UTC Only)





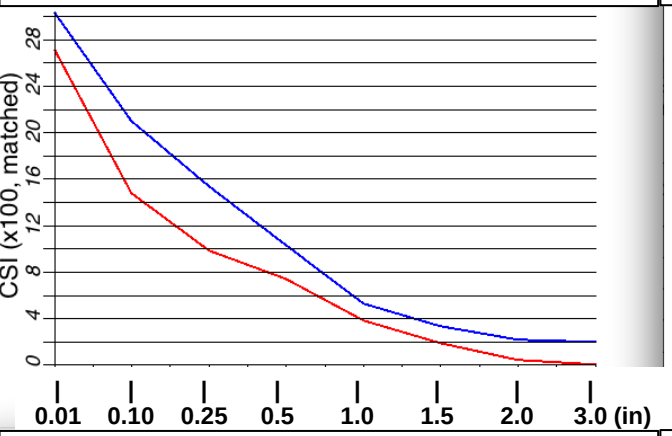


RAPv3 Retrospective Verification

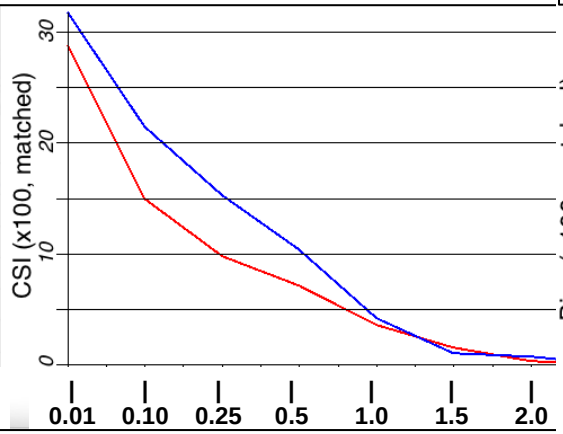
Eastern US 15 Jul – 15 Aug 2014 **Exper RAPv3** **Oper RAPv2**

RAP Eastern US Precipitation 6-hr Forecast

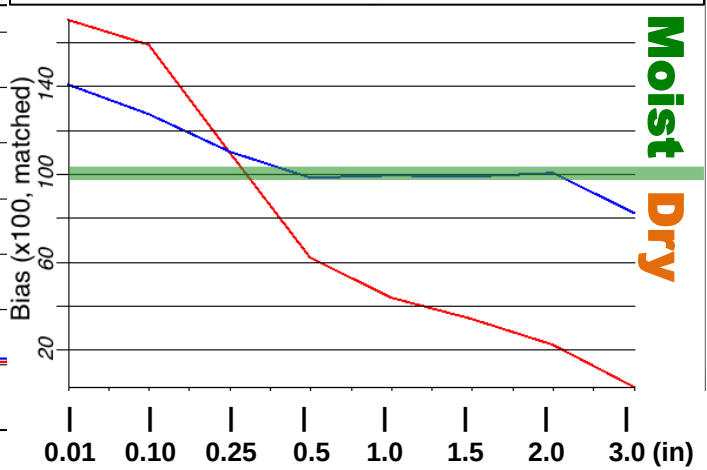
CSI 13-km



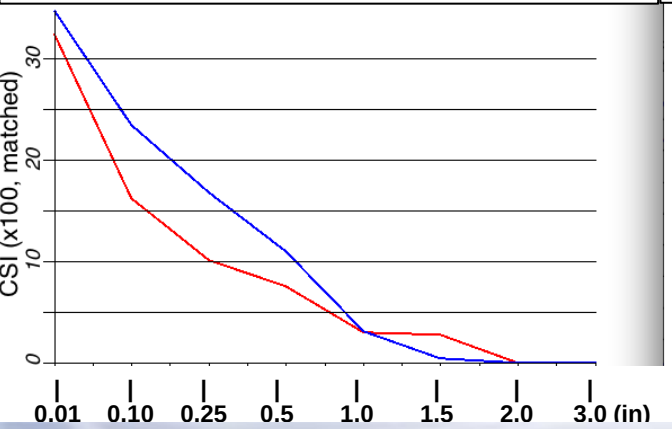
CSI 20-km



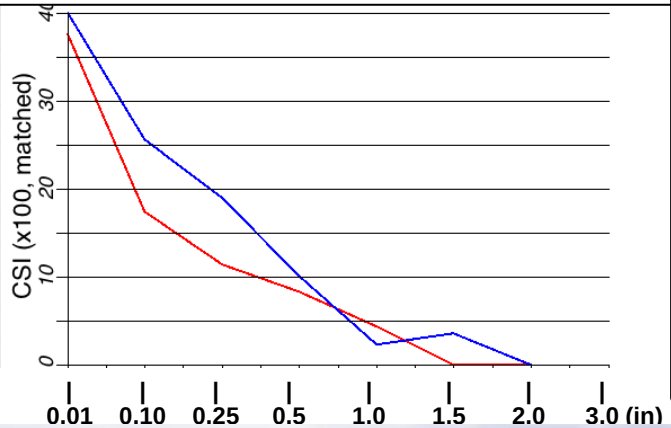
BIAS 13-km



CSI 40-km



CSI 80-km



Reduced moist bias at low precip thresholds

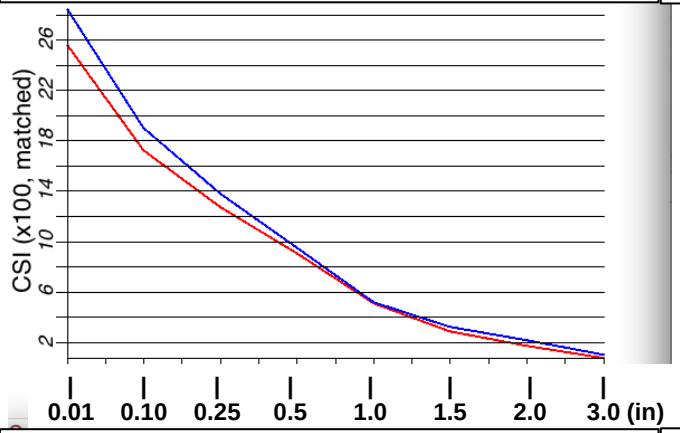
Reduced dry bias at high precip thresholds

HRRRv2 Retrospective Verification

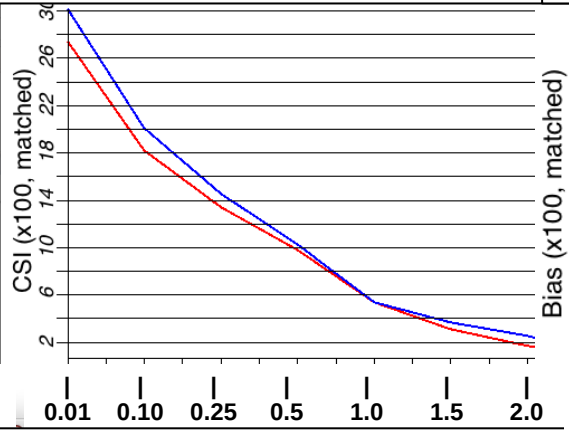
15 Jul – 15 Aug 2014 **Exper HRRRv2** **Real-time HRRR**

HRRR Eastern US Precipitation 6-hr Forecast

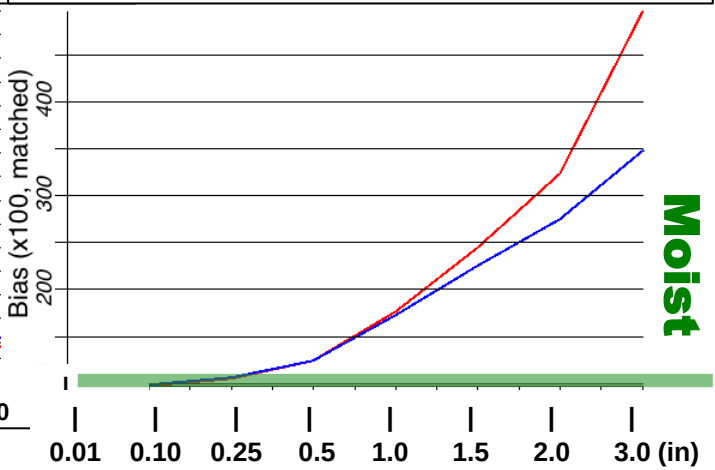
CSI 3-km



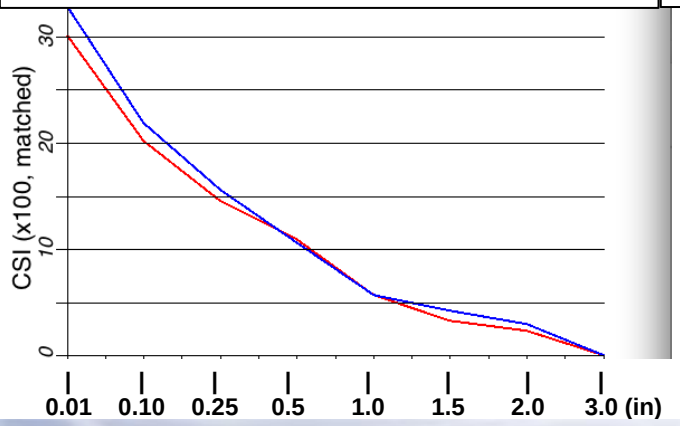
CSI 20-km



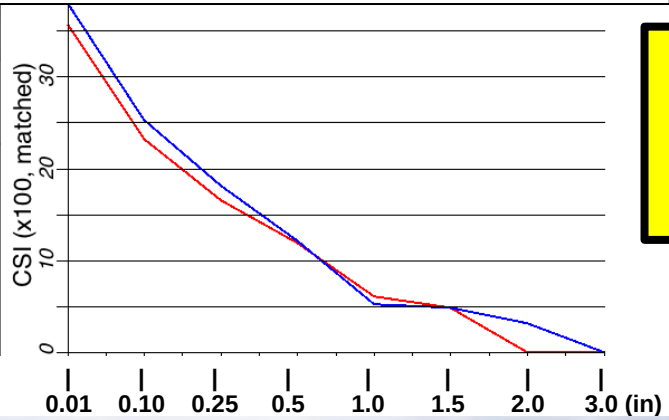
BIAS 3-km



CSI 40-km

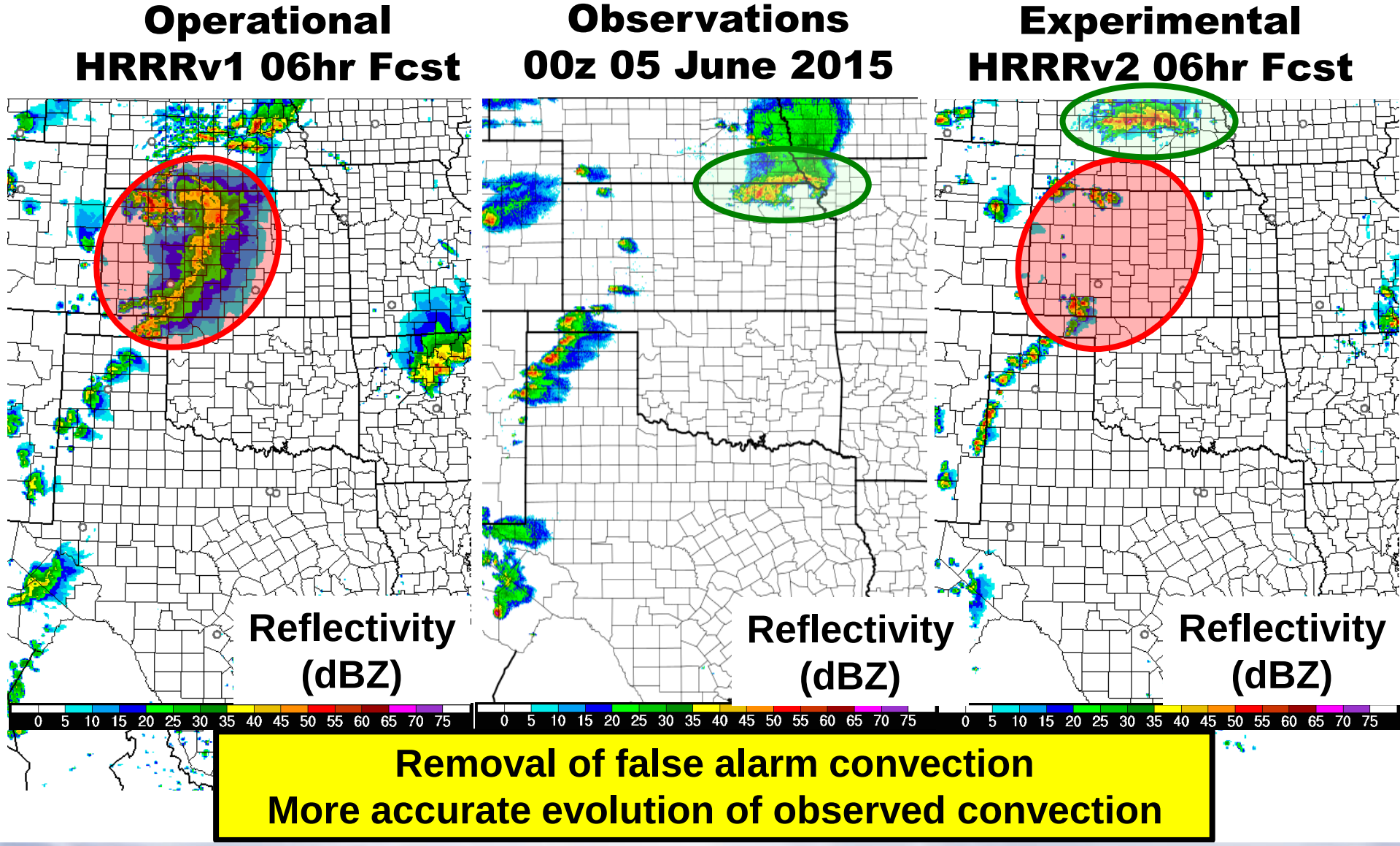


CSI 80-km



Reduced moist bias at high precip thresholds

HRRR Convective Case Study



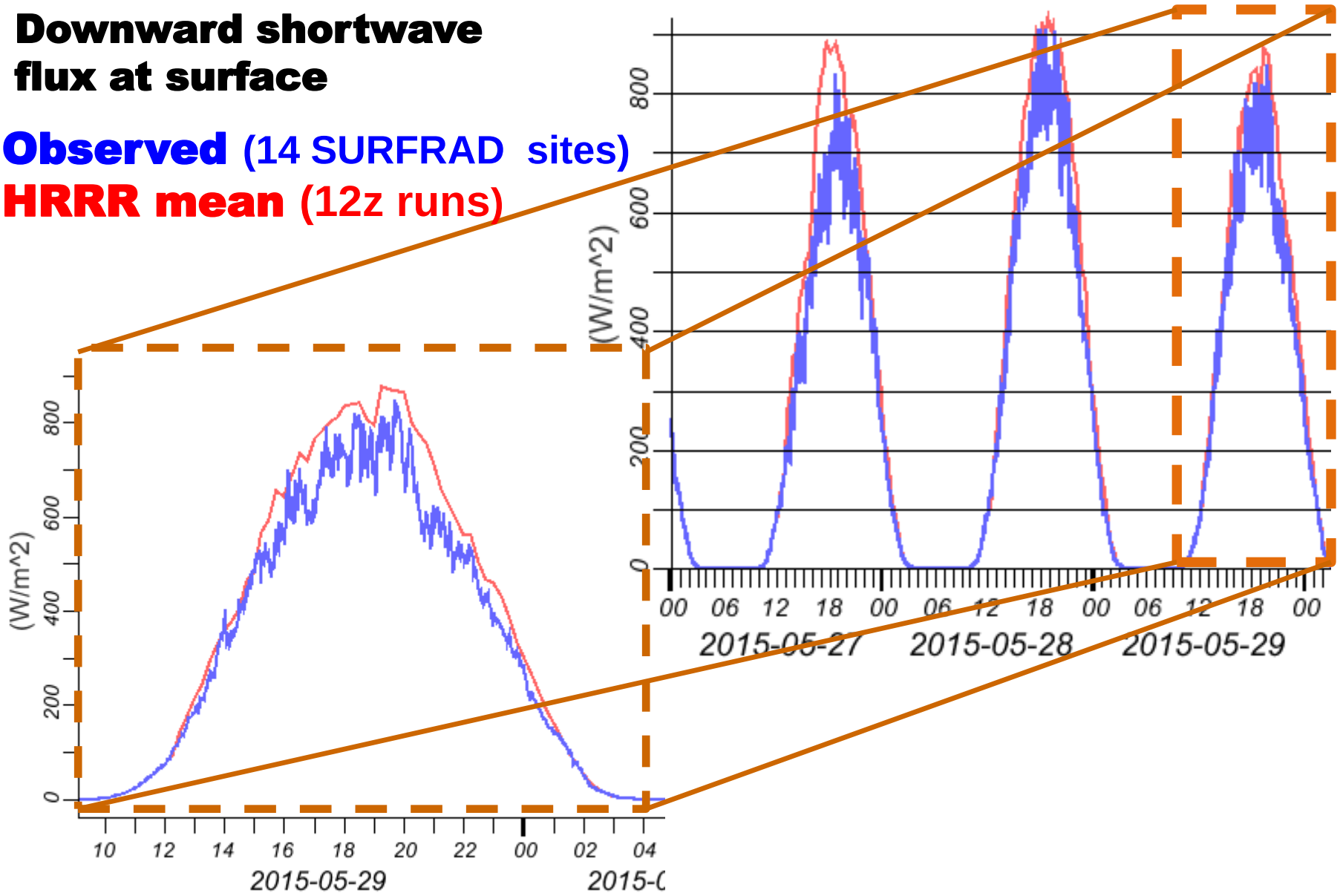
Removal of false alarm convection
More accurate evolution of observed convection

15-min Validation of HRRR forecasts

Downward shortwave flux at surface

Observed (14 SURFRAD sites)

HRRR mean (12z runs)



RAPv3/HRRRv2 vs. RAPv2/HRRRv1

Winds -- Consistent RAPv3 improvement for both upper-air and surface, for all seasons

Temperature – Reduced low-level warm bias for warm season afternoon / evening. Improved upper-level temperature forecasts

Moisture – Reduced low-level dry bias for warm season afternoon / evening. Improved upper-level relative humidity forecast

Precipitation – Slight improvement, reduced low thresh high bias / increased high thresh low bias

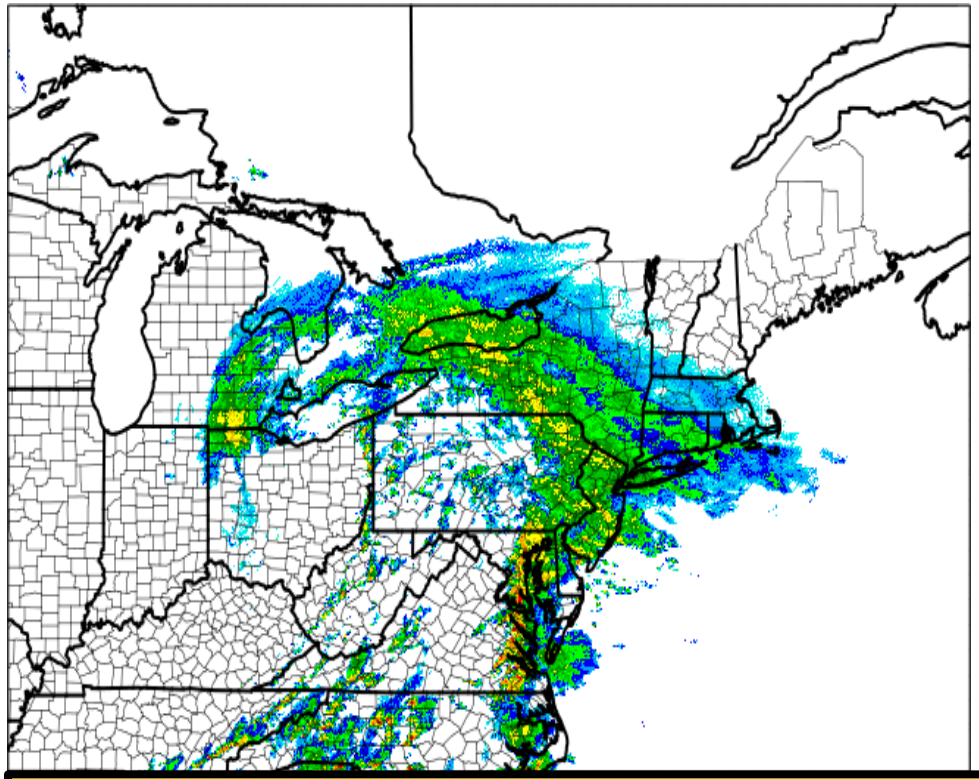
RAP/HRRR Implementation Map

ESRL – experimental version	NWS-NCEP - operational
• **RAPv3 – GSD testing in 2014-15** – Is initializing 2015 ESRL-HRRR(v2) – Improved PBL, LSM, cu-parm, DA – WRFv3.6.1 w/ Thompson/NCAR aerosol-aware microphysics	→ • Implement late 2015
• **HRRRv2 – GSD testing in 2014-15** – Initialized by 2015 RAP (v3) – Improved radar assimilation, hybrid assimilation, PBL/cloud physics	→ • Implement late 2015
• **RAPv4 – GSD testing in 2015** – Hourly RAP ensemble data assimilation	→ • Implement 2016
• **HRRRv3 – GSD testing in 2015** – Improved 3km physics – Full 3-km hourly cycling w/radial vel – Cycling of aerosols with fire/emissions	→ • Implement 2016

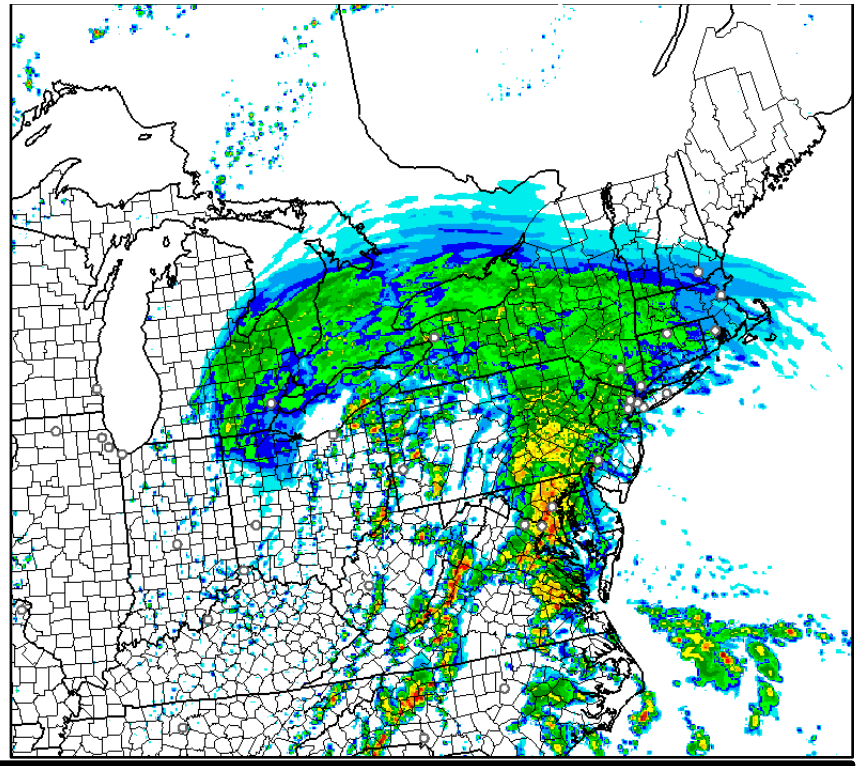
Experimental RAP/HRRR 24hr Fcst Length

http://rapidrefresh.noaa.gov/HRRR (24 hrs)
http://rapidrefresh.noaa.gov/RAP (30 hrs)

Observations
21z 27 June 2015

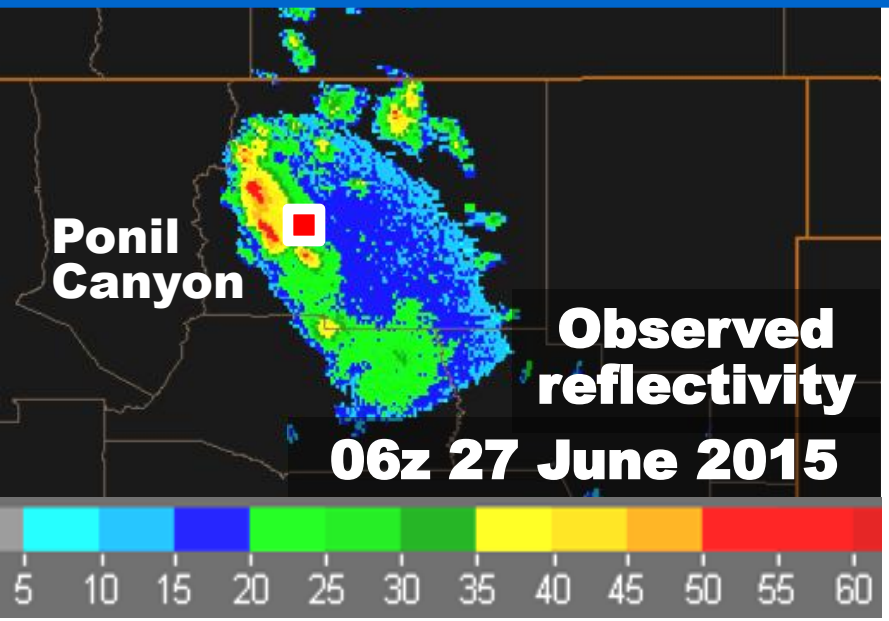


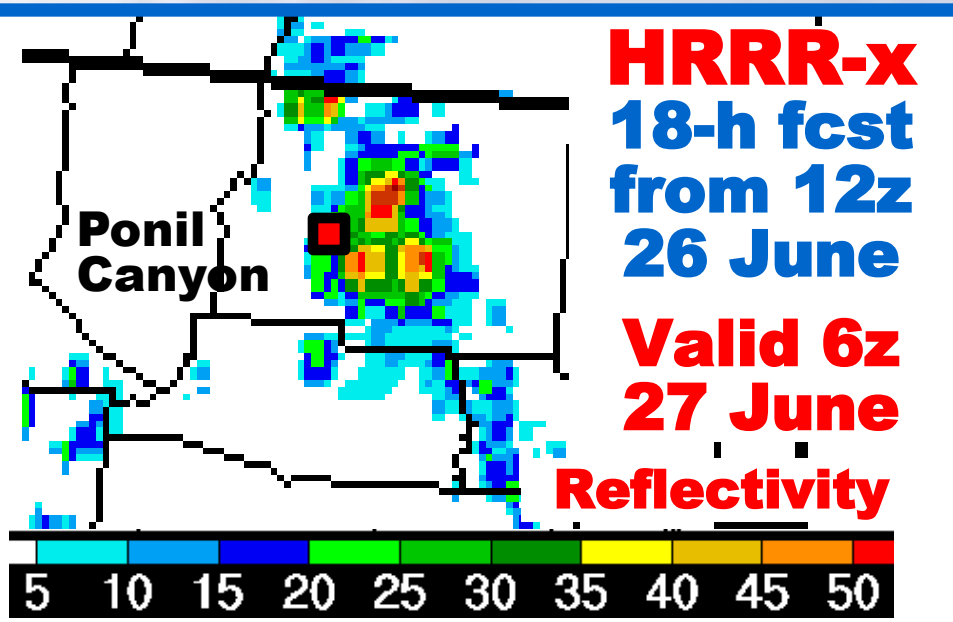
Exper HRRRv2 21hr Fcst

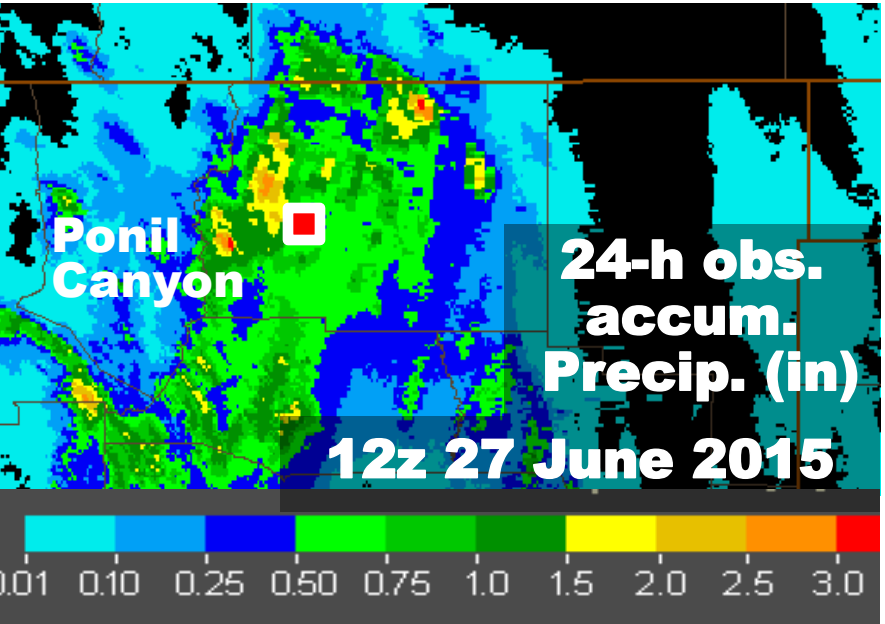


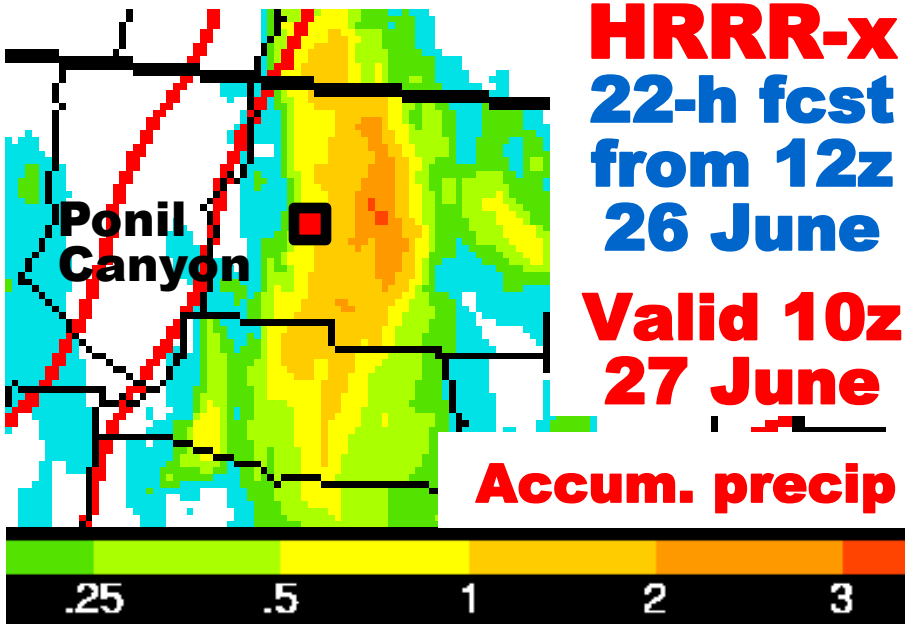
Longer Forecasts To Cover Day One Forecast Products (WPC, SPC…)
Longer Lead-Time Forecasts for High-Impact Events
More Members in Time-Lagged Ensemble

Philmont Scout Ranch Flash Flood Fatality









Philmont Scout Ranch Flash Flood Fatality